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Design of Rigid Pavement by Using Fly Ash as a Stabilizing Material

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ABSTRACT:
Fly ash is the waste material, which is obtained after burning coal in thermal power plants. It can be used as a stabilizer for soil due to its pozzolonic effect or an inherent self hardening property under favorable conditions of moisture and compaction. This project aim is to study the effect of fly ash on an expansive soil for rigid pavement design and to reduce the quantity of lime in lime fly ash by the effective use of fly ash itself. Some percentage of fly ash without any additive was utilized so as to reduce the cost of construction and this is a good method for disposal of it. Initially the index properties of the soil were studied by conducting liquid limit, plastic limit, shrinkage limit, grain size analysis and specific gravity tests. CBR, OMC and swell index tests confirmed that the soil had taken was clay which is highly expansive in nature.

Compressive strength and soaked CBR tests will be conducted for various proportions of Fly ash and optimum contents were obtained and found that soil strength improved. If the locally available soil is good in nature pavement construction becomes easier and cheaper. But if the soil is weak in nature instead of going for an alternative, which costs higher the available soil can be modified by adding this type of stabilize which involves low cost.

Pavement foundations are treated with fly ash for a variety of reasons: for construction facilitation, treatment of expansive soils, and to provide structural support for the pavement system. Many studies have shown that well engineered and constructed lime stabilized soil layers provide strong and durable support to pavement structures, improving their long term performance. And the project is undertaken by K.V. infrastructures located at Ellareddyguda flat no: 402, pragathi enclave, near meeseva Srinagar colony.

1. INTRODUCTION

Fly ash is a finely divided residue resulting from the combustion of ground or powdered coal and transported by the flue gases of boilers fired by pulverized coal. It is available in large quantities in the country as a waste product from a number of thermal power stations and industrial plants using pulverized coal as fuel for the boilers. At present there are more than 40 thermal power plants in the country producing over 5 million tones of fly ash per annum. The ash content of the coal used at most of these plants range from 17 to 45 percent. Since low ash, high grade, coal is reserved for metallurgical industries, railways, etc., the thermal power plants have to utilize high ash, low grade, coal and by-product fuel from coal washeries. It has been estimated that the average ash content of coal which will be available for thermal power plants in the coming years may range between 35 and 45 percent.

Fly ash may be collected from the flue gases, in thermal power plants, by mechanical collectors, electrostatic precipitators or a combination of both. It may be removed by ‘wet system’ or ‘dry system’ of ash removal. The ‘wet system’ involves mixing the fly ash with water and sluicing it to a settling tank or dumping areas. The ‘dry system’ involves removal of the fly ash in dry form either directly by screw feeders discharging into transport vehicles from the hoppers or by means of pneumatic conveying system for further disposal..

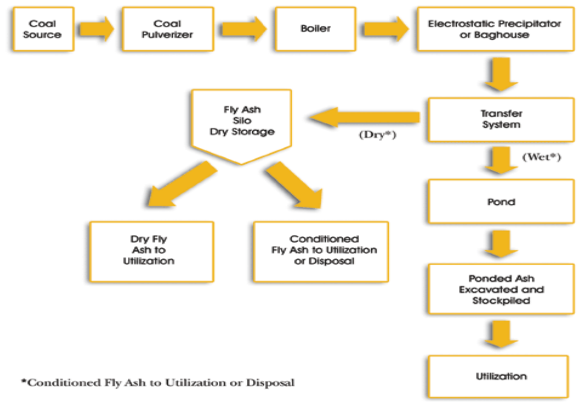

Fig: Method of fly ash transfer can be dry, wet, or both**.**

1.1 SIGNIFICANCE AND USE

Self-cementing coal fly ashes are suitable materials for the stabilization of soils, recycled pavement materials and road surface gravel. Fly ash stabilization can result in improved properties, including increased stiffness, strength and freeze-thaw durability; reduced hydraulic conductivity, plasticity, and swelling; and increased control of soil compressibility and moisture. Fly ash stabilized materials (FASM) may be used in roadway construction, such as working platforms during construction, stabilized sub grade, sub base, and base layers. Fly ash stabilization can also be used in limiting settlement of fills below buildings. The degree of success attained in stabilization with coal fly ash is highly dependent on the particular combination of soil, fly ash, and other additives and the construction procedure used. The selection of appropriate materials, applicable tests, acceptance criteria, and specification is the responsibility of the design engineer.

2. LITERATURE REVIEW

2.1 GENERAL

Pavement consists of more than one layer of different material supported by a layer called sub grade. Generally pavement is two type flexible pavement and rigid pavement. Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of material.

2.2 TYPES OF PAVEMENTS

Based on structural behavior, the pavements are broadly classified into three categories as follows;

1. Flexible Pavement
2. Rigid Pavement
3. Composite Pavement

2.2.1 Flexible Pavements

A flexible pavement structure is typically composed of several layers of material with better quality materials on top where the intensity of stress from traffic loads is high and lower quality materials at the bottom where the stress intensity is low. Flexible pavements can be analyzed as a multilayer system under loading.

2.2.2 Rigid Pavement

A rigid pavement structure is composed of a Pavement Quality Concrete (PQC) surface course and underlying Dry Lean Concrete (DLC) base and a typical subbase courses of GSB layer to act as a drainage layer. Another term commonly used is Portland cement concrete (PCC) pavement, although with today's pozzolanic additives, cements may no longer be technically classified as "Portland."

2.2.3 Composite Pavement

A composite pavement is composed of both hot mix asphalt (HMA) and hydraulic cement concrete. Typically, composite pavements are asphalt surfaces on top of concrete stabilized base/ sub-bases. The HMA surface may have been placed as the final stage of initial construction, or as part of a rehabilitation or safety treatment. Composite pavement behavior under traffic loading is combination of flexible cum rigid pavements. The fatigue life of stabilized base/ sub-base may calculate as similar as rigid pavements and HMA surface layer fatigue life will evaluate as per the standard design procedure flexible pavements.

2.2.4 Rigid and Flexible Pavement Characteristics

The primary structural difference between a rigid and flexible pavement is the

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manner in which each type of pavement distributes traffic loads over the sub-grade. A rigid pavement has a very high stiffness and distributes loads over a relatively wide area of sub-grade – a major portion of the structural capacity is contributed by the slab itself.

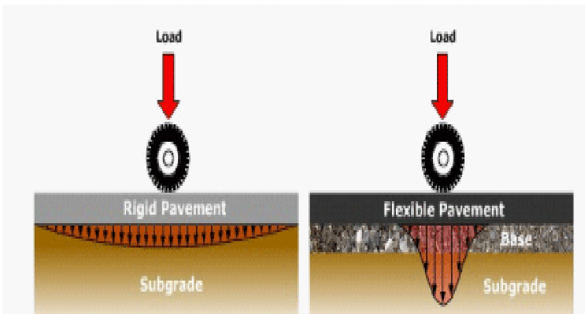

Fig: Typical Stress Distribution Diagrams of Rigid and Flexible Pavements

Over the past decades worldwide many researches has contributed for improving the properties of concrete while significant research has been performed to describe the importance of the peak strength and initial elastic modulus, further work is needed to how damage develops and influences the stiffness degradation and energy dissipation of concrete.

3. HIGHWAY APPLICATIONS

Fly ash is used in concrete admixtures to enhance the performance of concrete. Portland cement contains about 65 percent lime. Some of this lime becomes free and available during the hydration process. When fly ash is present with free lime, it reacts chemically to form additional cementitious materials, improving many of the properties of the concrete.

3.1. Fly Ash in Structural Fills/Embankments

Fly ash can be used as a borrow material to construct fills and embankments. When fly ash is compacted in lifts, a structural fill is constructed that is capable of supporting highway buildings or other structures. Fly ash has been used in the construction of structural fills/embankments that range from small fills for road shoulders to large fills for interstate highway embankments.

3.2 Fly Ash in Soil Improvement

Fly ash is an effective agent for chemical and/or mechanical stabilization of soils. Soil density, water content, plasticity, and strength performance of soils. Typical applications include: soil stabilization, soil drying, and control of shrink-swell. The rate of the hydration reaction upon exposure to water. Soil moisture content at the time of compaction. Fly ash with sulphate content greater than 10 percent may cause soils to expand more than desired. In many cases, leaching tests may be required by local and state agencies.

3.3 Fly Ash in Asphalt Pavements

Fly ash can be used as mineral filler in HMA paving applications. Mineral fillers increase the stiffness of the asphalt mortar matrix, improving the rutting resistance of pavements, and the durability of the mix. Fly ash will typically meet mineral filler specifications for gradation, organic impurities, and plasticity. The benefits of fly ash include: Reduced potential for asphalt stripping due to hydrophobic properties of fly ash Lime in some fly ashes may also reduce stripping. May afford a lower cost than other mineral fillers

3.4 Fly Ash in Grouts for Pavement Sub sealing

Grouts are proportioned mixtures of fly ash, water, and other materials used to fill voids under a pavement system without raising the slabs (sub sealing), or to raise and support concrete pavements at specified grade tolerances by drilling and injecting the grout under specified areas of the pavement. Fly ash grouts can Be used to correct undermining without removing overlying pavement. Be accomplished quickly with minimum disturbance to traffic. Develop high ultimate strength.

4. FLYASH IN PORTLAND CEMENT CONCRETE

The use of fly ash in Portland cement concrete (PCC) has many benefits and improves concrete performance in both the fresh and hardened state. Fly ash use in concrete improves the workability of plastic concrete, and the strength and durability of hardened concrete. Fly ash use is also cost effective. When fly ash is added to concrete, the amount of Portland cement may be reduced.

4.1 Benefits to Fresh Concrete

Generally, fly ash benefits fresh concrete by reducing the mixing water requirement and improving the paste flow behavior.

Fig: Fly ash improves workability for pavement concrete

- **Decreased water demand.** The replacement of cement by fly ash reduces the water demand for a given slump. When fly ash is used at about 20 percent of the total cementitious, water demand is reduced by approximately 10 percent. Higher fly ash contents will yield higher water reductions. The decreased water demand has little or no effect on drying shrinkage/cracking. Some fly ash is known to reduce drying shrinkage in certain situations.
- **Reduced heat of hydration.** Replacing cement with the same amount of fly ash can reduce the heat of hydration of concrete. This reduction in the heat of hydration does not sacrifice long-term strength gain or durability. The reduced heat of hydration lessens heat rise problems in mass concrete placements.
- **Increased ultimate strength.** The additional binder produced by the fly ash reaction with available lime allows fly ash concrete to continue to gain strength over time. Mixtures designed to produce equivalent strength at early ages (less than 90 days) will ultimately exceed the strength of straight cement concrete mixes.

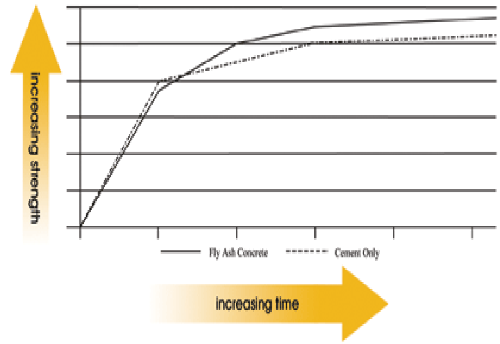

Fig: Typical strength gain of fly ash concrete.

- **Reduced permeability.** The decrease in water content combined with the production of additional cementitious compounds reduces the pore interconnectivity of concrete, thus decreasing permeability. The reduced permeability results in improved long-term durability and resistance to various forms of deterioration.

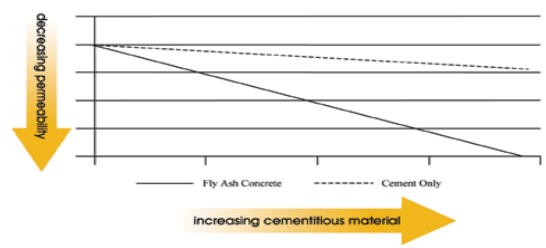

Fig: Permeability of fly ash concrete.

- **Improved durability.** The decrease in free lime and the resulting increase in cementitious compounds, combined with the reduction in permeability enhance concrete durability.

4.2 Soil Stabilization to Control Shrink Swell

Many clay soils (plastic soils) undergo extensive volumetric changes when subjected to fluctuating moisture contents. These volumetric changes if not controlled can lead to movements in structures and impose loads which can cause

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premature failure. The plasticity of soils has historically been quantified by the plasticity index, as determined by ASTM D 4318. Typically specifications limit the plasticity index of a soil to no more than 10-12 to ensure a stable material. In general terms, the higher the plasticity index, the higher the potential to shrink or swell as the soil undergoes moisture content fluctuations. The swell potential of fly ash treated soils is typically less than 0.5 percent under confining pressures of 48 kPa (100 psf) even when compacted two to four percent below optimum moisture content for maximum density.

5. RESULTS AND DISCUSSIONS

Twenty-seven specimens consisting of 9 cubes, 9 prisms and 9 cylinders castedwith three different plain normal-strength concrete grades (M20, M30 and M40) were tested under short-term uniaxial compression and two point bending test to determine the ultimate strength and to study the stress-strainbehaviour with different grade of concrete.

5.2 Compressive Strength of Concrete

For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were cast for M20, M30 and M40 grade of concrete. Vibration was given to the moulds using table vibrator. The top surface of the specimen was levelled and finished. After 24 hours the specimens were de-moulded and were transferred to curing tank wherein they were allowed to cure for 28 days. After 28 days curing, these cubes were tested on digital compression testing machine as per I.S. 516-1959. The failure load was noted.

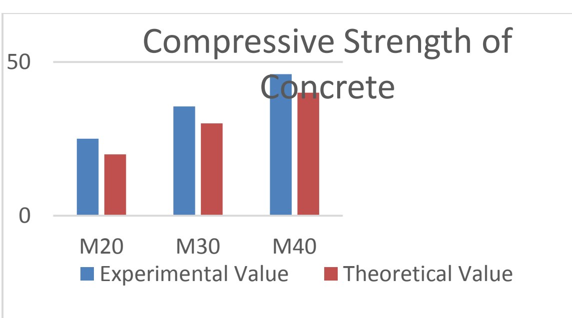

Fig: Comparison of Compressive Strength with Characteristic Strength

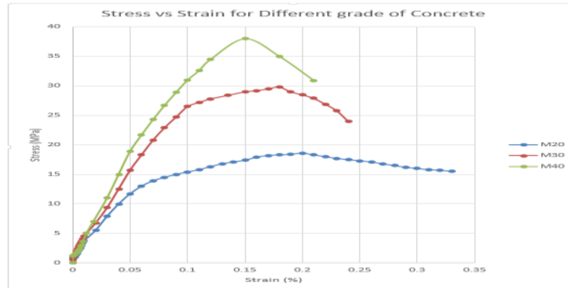

Fig: Stress vs Strain graph for different grades of concrete

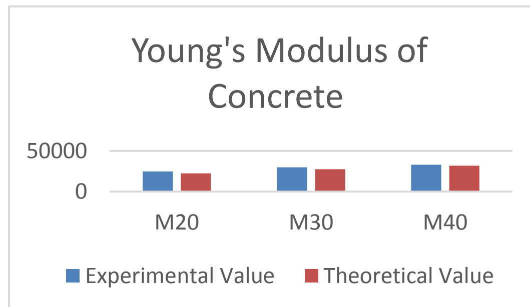

Fig: Comparison of Young's Modulus with theoretical value

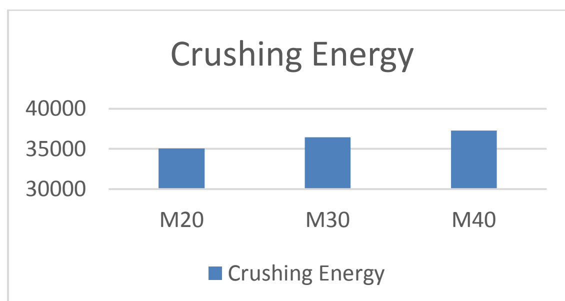

Fig: Comparison of Crushing Energies of different grade of Concrete

CONCLUSION

Maximum reduction in heave values are obtained for the lime-cement stabilized flash sub base stretch compared to other stretches on expansive soil subgrade. Heaving of the expansive soil has considerably decreased the load carrying capacity of flexible pavement system. By addition of fly ash, the CBR value is increased by 27% when compared to unmodified soil. Fly ash can be successfully used in the cement concrete road pavements. Though it lowers the rate of hydration as well as final strength, it makes the section economical. Hence it is a safe and environmentally consistent method of disposal of fly ash. Based on the Experimental Studies on M20 grade, M30 grade, M40 grade of concrete, the variation in mechanical properties of concrete is presented Compressive strength of concrete is found to be increasing with increase in the grade of concrete. This is may be due to reduction in the percentage voids and the increase in the toughness of the matrix with the increase in the grade of concrete. Flexural Strength of concrete is found to be increasing with increase in the grade of concrete. This is may be due to reduction in the percentage voids and the increase in the toughness of the matrix with the increase in the grade of concrete. Modulus of concrete is found to be increasing with increase in the grade of concrete. This is may be due to reduction in the percentage voids and the increase in the stiffness due to increase in the toughness of the matrix with the increase in the grade of concrete. Peak Strain is found to be decreasing with increase in the grade of concrete and Peak Strain is found to be increasing with increase in the grade of concrete, this may be due to the increase in the stiffness and brittleness of concrete with the increase in the grade of concrete. Failure stress is observed to be increasing with increase in the grade of concrete and the failure strain is observed to be decreasing with increase in the grade of concrete. The difference between failure strain and peak strain is decreasing; this may be due to increase in the brittle nature of the concrete.The Crushing Energy of the concrete increases with the grade of concrete because the energy storing capacity of concrete increases with the compaction of concrete and becomes stronger and bears more loads.

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